

THE RÔLE OF VERTEBRATES IN THE CONTROL OF INSECT PESTS *

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[With 7 plates]

That vertebrates eat insects is common knowledge. What their destruction of these creatures means to the welfare of man, however, is appreciated by comparatively few. Indeed, even at this late date, it must be confessed that we know so little about the food habits of vertebrates other than birds that it is impossible to give a very satisfactory account of them. The unavoidable result of this situation is that the present paper while technically embracing all of the vertebrates, practically is devoted very largely to birds.

However, to give other members of the backboned clan their due, we may begin by adverting to a fact made familiar by the work of the Bureau of Fisheries, as well as by that of the Bureau of Entomology, that certain small fishes are effective enemies of mosquito larvæ, and that they can be used to advantage by man in his warfare against these pests. This seems to be the only outstanding credit to the fishes, although trout, and no doubt other fishes in infested waters, devour many black-fly larvæ. The feeding of fishes on land insects dropping into the water is of little economic significance, because desultory, and affecting individual insects, a large proportion of which would be eliminated anyway by drowning.

Among the class that is ranged next to the fishes—namely, the amphibians—we have numerous insectivorous forms, but because of their aquatic habitat many of them come but little in contact with insects injurious to man. The toads constitute a striking exception to this rule, especially the common forms that frequent cultivated fields and gardens. Toads are practically omnivorous in relation to invertebrates occurring in their habitat, and if an insect living on or near the ground is abundant enough to be the cause of damage we may be sure that any toads in the area will be feeding upon it. The common toad has a good record as a predator upon millipedes, ants,

cutworms, the army worm, tent caterpillar, gypsy caterpillar, June bugs, rose chafer, potato beetle, and the alfalfa weevil.

The food-habits of the class of reptiles are less definitely known than those of any other vertebrates. So far as snakes are concerned it appears that only a few of the smaller species are decidedly insectivorous, and they are such comparatively scarce animals that they can have but little effect upon the numbers of insects. The turtles, being chiefly aquatic, are in the same position as the water-loving amphibians—that is, they come in very slight contact with insects noxious to man. The lizards are highly insectivorous, but are rather meagerly represented over most of the United States. Some of the western and southwestern species, however, appear to be important enemies of grasshoppers and ants, and to be generally useful as insect destroyers. In hot countries lizards are more numerous, active, and voracious, and have been credited by some writers with being as valuable individually as are insectivorous birds.

Among mammals we have some highly insectivorous groups as the bats, shrews, and moles. The exact nature of the food of bats is little known but it includes all sorts of flying insects of sizes these animals can swallow, including mosquitoes, but the latter certainly to no such extent as has sometimes been claimed. Shrews and moles get numerous ants, wireworms, cutworms, and white grubs, and doubtless do more good than harm. The short-tailed shrew has proved to be one of the principal enemies of the larch sawfly and in New Brunswick, it has been ascertained that 40 per cent of the cocoons are destroyed by this shrew. Arboreal squirrels sometimes feed freely on scale insects and other tree pests; the western ground squirrels eat quantities of injurious insects, such as cutworms, wireworms, and grasshoppers; and the so-called grasshopper mice perhaps deserve their name, and undoubtedly are more highly insectivorous than the majority of their tribe. The armadillo, which occurs in the United States only in Texas, is a voracious consumer of insects, especially white grubs and their adults, caterpillars, and ants, and the badger occasionally makes a hearty meal of grasshoppers, immature cicadas, or beetles. Of our larger mammals, skunks certainly are the greatest enemies of insects. Army worms, tobacco worms, and white grubs are favorite prey of these animals. In Manitoba, Mr. Norman Criddle, field officer, Canadian Entomological Service, estimated that on one 8-acre tract skunks destroyed 14,520 white grubs to the acre. Cutworms, the potato beetle, and grasshoppers are other insect pests eaten by skunks, and the common eastern skunk once proved so efficient an enemy of the hop grub in New York, that the first

legislation protecting the animal in that State was passed at the demand of the hop growers. Investigations in New Mexico by the Biological Survey showed skunks also to be the most important natural enemies of the range caterpillar.

While we must confess that we do not know as much about the food habits of vertebrates, other than birds, as we should know and as we shall know when investigations now in progress are completed, we can safely assert that no investigation is likely to upset the present assumption that as enemies of insects, birds stand supreme among vertebrates. If for no other reasons, we are thus confident because birds are more numerous in species and individuals than other insectivorous vertebrates, and their greater mobility enables them to concentrate quickly where unusual food supplies become available—that is, at the scene of insect outbreaks.

The most extensive studies of the food of birds ever made have been carried on by the United States Biological Survey, but these investigations for the most part have been directed toward learning what birds eat in general, rather than determining the explicit effect of their food habits upon certain insects or other pests. The Survey has a great store of data as to the items of bird food, and the numbers and proportions in which they are taken; it can furnish comprehensive lists of the bird enemies of a vast number of insects, but it is not in a position to report from its own resources, what degree of control birds attain over this or that particular insect pest.

In fact opportunities to get such information come infrequently and the observers most likely to be favored are the men in the field who are working continuously upon an insect outbreak. These men, usually, are economic entomologists, numbers of whom, fortunately, have made good use of their opportunities, and it is largely upon their work that the remainder of this article is based. The writer is the more justified in quoting their findings so freely since economic ornithology, not only in this, but in other countries, has been fostered and inspired chiefly by entomologists.

Among the earliest champions of the value of birds in this country were Dr. William Le Baron, of Illinois, and Dr. Isaac P. Trimble, of New Jersey, both well-known entomologists. These gentlemen did not neglect the examination of the contents of bird stomachs, but it may be a surprise to learn that Dr. Townend Glover, first entomologist of the United States Department of Agriculture, not only examined the stomach contents of many birds, but had in the old agricultural museum a collection of mounted birds with their food in vials beside them. Furthermore, one of his annual reports, that for 1865, was devoted largely to a general account of the economic value of birds including results of his original investigations. The United

States Entomological Commission of the seventies did not fail to give due credit to bird enemies of the insect pests it studied, and in the report on the Rocky Mountain locust, gave to the world the most extensive paper on the food of birds that had appeared up to that time. The researches and philosophical writings of Dr. S. A. Forbes, of Illinois, during the eighties earned for him the name of founder of the science of economic ornithology. The Biological Survey which has carried the study of the economic relations of birds farther than has ever been done elsewhere, had its origin as a section of economic ornithology in what then was the Division of Entomology. Although this arrangement did not last long, the first two reports published by the new organization on the food of insectivorous birds contained technical sections on the insect food, written by those eminent entomologists, Dr. C. V. Riley, and Dr. E. A. Schwarz.

Not only did entomologists have much to do with the origin and establishment of economic ornithology in this country but their interest in the subject has been actively maintained to the present day. References to the value of birds are especially numerous in the writings of the later entomologists, Lintner, Slingerland, and Hewitt, among the deceased, and among the living, Weed, Bruner, Sanderson, Felt, Hopkins, and Chittenden. In Canada Dr. John D. Tothill has been especially active and has published a series of splendid papers on the natural control of insects, in every one of which birds have been given great credit.

In a recent work on the Principles of Insect Control,¹ the authors, Messrs. Robert A. Wardle and Philip Buckle, devote an entire chapter to bird encouragement. In summing up the economic status of British birds they state that the "cuckoos, swifts, lapwings, woodpeckers, and the majority of Passerine birds, particularly Paridæ (tits), Turdidæ (thrushes), Muscicapidæ (flycatchers), and Hirundinidæ (swallows), are of the utmost value" (p. 61).

Having by now made the impression, the writer hopes, that economic ornithology after all is very much an entomological subject, we will proceed to a systematic discussion of the value of birds in insect control. But while so doing we must avoid anthropomorphic reasoning to the effect that birds prey upon this or that insect to assist mankind. On the contrary, whatever they do in the way of feeding upon insects is for reasons entirely their own, but it so happens that in carrying on their customary activities they sometimes do great good in the suppression of insect pests.

We must remember also that insects are not the sole food of birds but that the birds draw on all the sources of food available to them,

¹ Manchester Univ. Press, 1923, 295 pp.

including the vegetable as well as the animal kingdom. Probably half of the total food of birds in general is of vegetable origin. Again, all sorts of animals from protozoans to mammals are eaten, and insects do not contribute more than their due proportion. In short, we must bear in mind that birds feel no obligation to help us, nor do they, as we might wish, feed exclusively upon insects. These limiting factors understood, we shall be the more able to appreciate the activities of birds at their true worth.

Despite the adaptive radiation in food habits which birds exhibit, and which leads to more or less specialization in various groups, few kinds are so absolutely bound to peculiar feeding methods that they can not forsake them temporarily when some food becomes available in unusual abundance. For a simply stated illustration of this phenomenon the writer draws on Dr. Isaac P. Trimble, the pioneer economic entomologist of New Jersey, who, in his Treatise on the Insect Enemies of Fruit and Fruit Trees, published in 1865, wrote:

On the 5th of May, 1864, I shot seven different birds; they had all been feeding freely on small beetles, and some of them on nothing else. There was a great flight of these small beetles that day; the atmosphere was teeming with them. A few days later, the air was filled with ephemeræ flies, and the same species of birds were then feeding upon these (p. 113).

A more elaborate example of the same tendency on the part of birds is Prof. Samuel Aughey's findings during his studies of bird enemies of the Rocky Mountain locust in the sixties and seventies. Tempted by the abundance and accessibility of these insects, birds of every kind flocked to the feast. Land birds and water birds, tree frequenters and plains dwellers, whether normally fish, flesh, seed, or fruit eaters—all, from the diminutive humming bird to the largest hawks, came to feed upon grasshoppers.

Not only is a further striking instance of this phenomenon recorded by Dr. S. A. Forbes as a result of his study of birds in relation to cankerworms in Illinois, but the conclusions to be drawn are stated so clearly as to be well worth quoting. Dr. Forbes says:

Birds of the most varied character and habits, migrant and resident, of all sizes, from the tiny wren to the bluejay, birds of the forest, garden and meadow, those of arboreal and those of terrestrial habit, were certainly either attracted or detained here by the bountiful supply of insect food, and were feeding freely upon the species most abundant. That 35 per cent of the food of all the birds congregated in this orchard should have consisted of a single species of insect, is a fact so extraordinary that its meaning can not be mistaken. Whatever power the birds of this vicinity possessed as checks upon destructive irruptions of insect life was being largely exerted here to restore the broken balance of organic nature.²

² Forbes, S. A.: The Regulative Action of Birds upon Insect Oscillations, Bull. Ill. State Laboratory of Natural History, Vol. I, No. 6, May, 1883, pp. 20-21.

Whether the pressure thus put on irruptions of insects is ever effective in securing a worth while degree of control is a topic upon which it is natural to be skeptical. Insects are so numerous and propagate so rapidly that it would seem they would always evade control by so limited a force as the bird population. Yet when we consider the results of the feeding habits of birds in other and more easily observed directions we begin to see that their consuming capacity is certainly impressive. For instance, consider the devouring of wild fruits by birds; it is quite the customary thing for a flock of birds to resort constantly to a certain tree or group of trees for food until the entire crop of fruit is consumed. This process is illustrated nearly every year in the parks of Washington. When the spring migrating impulse is on, cedar birds usually come to the parks in large numbers, and it is their habit to devote themselves to one kind of berry until it is gone. For instance, should they begin on holly they will finish all the holly berries in the Smithsonian Grounds, let us say, then they will next be found in the Capitol Grounds or in some other park working on the hollies there. Then they may turn their attention to cedar berries, if there is a crop, or to barberries, or to other fruit available. I have observed in various years that after cleaning up the berries they have even consumed the pods of the *Sophora* trees, feeding wastefully upon them at first, but later descending to the ground to go over again the remnants of the feast. I have seen on different occasions flocks of blackbirds, or of purple finches, or robins consume the entire crop of dogwood berries, not only of one or a few trees, but of all the trees in a woodland. Indeed, this manner of feeding is quite characteristic of birds.

If birds can do such things, if they consume in a brief time all the berries on a tree, is it not equally possible that they can consume likewise all of the insects? The answer is an emphatic and indisputable "yes." Such clean-up work not only can be, but has been done, and there is here given a summary of the recorded instances so far as they have been assembled.

For convenience the cases are arranged by orders of insects, and it will be understood when the word control is used, that our authority has made a statement indicating a high degree of control, and the word suppression when the insect concerned has been locally extirpated. The latter cases have already been treated at length in an article entitled "Local Suppression of Insect Pests by Birds," published in the Smithsonian Report for 1920.³ All data used in the following notes on control pertain either to the United States or Canada.

³ 1922. Pp. 411-438, 3 pls.

TERMITES OR WHITE ANTS (ISOPTERA).

At least three times the writer has personally made the observation, and he has had similar reports from others, that English sparrows, discovering a swarm of winged termites emerging from the nest, prey upon them so persistently that but few individuals escape.

GRASSHOPPERS AND CRICKETS (ORTHOPTERA).

There are at hand 31 instances of control and 19 of suppression of these insects in 13 States and 1 Canadian province. Among the authorities for the statements are included the following entomologists: Prof. Cyrus Thomas, Prof. Lawrence Bruner, Dr. E. Dwight Sanderson, Mr. Norman Criddle, Dr. H. C. Severin, and Messrs. A. C. Burrill, J. R. Horton, C. E. Pemberton, C. L. Corkins, and Max Reeher. Doctor Sanderson, in his report⁴ on the differential locust (*Melanoplus differentialis*) in Texas, states that birds "undoubtedly did more than any other natural agency to check the pest." Mr. Reeher remarks that birds were so efficient in controlling the coulee cricket (*Peranabrus scabricollis*) in the Dry Coulee region, Washington State, in 1918, that arrangements for a 1919 control campaign were abandoned. Meadowlarks were almost entirely responsible for a complete clean-up of the area.⁵

Mr. C. C. Clute relates the following instance of money saved through attracting bird enemies of grasshoppers in Iowa:

I know one farmer in particular who lost during one summer three rows of corn 40 rods long. The corn grew next to a fence row heavily sodded with bluegrass, which produced swarms of grasshoppers. For the sake of the experiment alone, for this farmer was a skeptic, last spring he put up 21 bird houses, placed 2 rods apart, on the fence along the 40 rods. The houses were some that he and the boys had made, during the winter months, from dry goods boxes obtained in town. Thirteen of the 21 houses were inhabited during the following summer, 6 by wrens, 4 by bluebirds, and 3 by colonies of purple martins. The grasshoppers that summer made a rich living for the birds, and when the fall came that farmer had the satisfaction of gathering 23 bushels of corn from the three rows that grew next to the fence, right where there had been no corn at all the year before.⁶

An account of bird control of Orthoptera can hardly omit reference to the historic case of suppression of the Mormon cricket (*Anabrus simplex*) by California gulls in the early days in Utah. Hon. George Q. Cannon, speaking of this insect and its bird enemies

⁴ Bull. 57, U. S. Bur. Ent. 1906, p. 22.

⁵ In Burrill, A. C. Calif. Fish and Game, 6, No. 1, Jan., 1920, p. 38.

⁶ Iowa Conservation, January–March, 1917, Vol. I, No. 1, p. 12.

in an address before the Third National Irrigation Congress, in Denver, 1894, said:⁷

After our grain had been sown and our fields looked promising, black crickets came * * * by the millions and devoured our crops. I have seen fields of wheat as promising as they could be in the morning and by evening they would be as bare as a man's hand—devoured by these crickets. * * * To us who lived in Utah about that time it seemed there was a visitation of Providence to save us. Sea gulls came by hundreds and by thousands, and before the crops were entirely destroyed these gulls devoured the insects, so that our fields were entirely freed from them.

This testimony is corroborated by that of a correspondent of the first entomologist of the United States Department of Agriculture, Dr. Townend Glover, who records⁸ that "Mr. James McKnight, who lives in Salt Lake City, states that when the Mormons first emigrated to Utah this cricket appeared in immense swarms, destroying their whole crops of wheat, etc., and that the second year they also appeared, but providentially, or miraculously, as it was deemed by the Mormons, vast flocks of white gulls suddenly appeared and destroyed the crickets to such an extent as to almost eradicate them for the time being, thus saving the remainder of the crop, upon which alone the half-starved Mormons had to rely for food for the next season. Since that time these birds are held almost sacred in Utah." It may be added that a monument commemorating the valuable aid of the gulls has been erected in Salt Lake City at a cost of \$40,000.

CICADAS, PLANT LICE, ETC. (HOMOPTERA)

Among entomologists, Dr. John B. Smith, Prof. F. M. Webster, and Dr. C. R. Marlatt agree that the periodical cicada is practically doomed to extinction in city parks or other localities where numerous English sparrows have a chance at them. Five cases of practically complete local extirpation of this insect by these sparrows are on record for the States of Illinois, Ohio, New York, and the District of Columbia. Doctor Marlatt also records the absolute failure of these insects to establish themselves even after artificial planting of enormous numbers in the Agricultural Grounds, because of the attacks of crow blackbirds.

For the pear psylla Prof. M. V. Slingerland gives an instance of control by birds in New York, Mr. E. H. Forbush one of the suppression in Massachusetts, and Mr. H. A. Surface another for New York State. An account of the latter instance is of value in showing how birds were put to practical use in solving a problem in economic entomology.

⁷ Irrigation Age, Vol. VII, No. 4, pp. 188-189, Oct., 1894.

⁸ Rep. Commr. Agr., p. 79, 1871.

A prominent grower of pears in New York reported to us that he had lost many of his pear crops, amounting to thousands of bushels, by this pest, and in the fall, as it was present in great numbers on the trunks of the trees, it appeared that it would pass the winter there and destroy his crops again next year. However, the white-breasted nuthatches came to the orchard in numbers, and he encouraged them to remain by fastening pieces of fat meat in his trees and protected them from molestation. The nuthatches remained and fed on the pest all winter and cleaned up the trees so effectively that he could scarcely find any of the insects in the spring.⁹

In the case of plant lice we have one record by Mr. H. A. Surface, of control of the apple aphis, in Pennsylvania, and the following 5 cases of suppression: Pea louse, one in Massachusetts, by Mr. E. H. Forbush, and one in New Jersey, Dr. John B. Smith; rose aphis, one in California, Mr. H. M. Russell; and unidentified aphids, one in Washington State and one in Massachusetts.

The writer has made one investigation of the bird enemies of plant lice, the insect being the green bug or wheat aphis. On a 200-acre farm in North Carolina, where wheat, rye, and oats were severely attacked by green bugs, it was found that birds were very effective in destroying the pests. The outbreak was at its height during the migration season of such birds as the goldfinch and the vesper and chipping sparrows, which with other species on the farm numbered more than 3,000 individuals. It was found that these birds were destroying green bugs at the rate of nearly a million a day, and on days when additional flocks of migrants were present this destruction was doubled. During the season such numbers of birds flocked to the grain fields that the aphis infestation was reduced by an incalculable number. Destruction of the aphids was at its height during that stage of cool spring weather that permits the green bug to breed freely yet holds in check its parasites. It will readily be agreed that under such circumstances every economic entomologist would welcome the assistance of any agency that would account for one or two million green bugs daily on a single farm.

In two further items relating to Homoptera, birds are credited with being the most important enemies of the clover leaf hopper (*Agallia sanguinolenta*), and in one instance with locally extirpating black olive scales. These complete the instances on hand for the order, 3 being of control, and 14 of suppression.

TRUE BUGS (HETEROPTERA)

Contrary to the impression prevailing among many naturalists, birds feed rather freely on Heteroptera. Nevertheless, there are few instances of great activity in this direction by field observers. Prof.

⁹ Zool. Bull. Penn. Dept. Agr., Vol. V, No. 3, p. 79, July, 1907.

Franklin Sherman reports¹⁰ English sparrows as an efficient aid in keeping Harlequin cabbage bugs in check in Robeson County, N. C., and Dr. A. W. Morrill notes that his studies of natural enemies of the conchuela (*Pentatoma ligata*) "point to the strong probability that birds are the useful agents in the reduction of the numbers of the adults."¹¹

BEETLES (COLEOPTERA).

For the extensive order of Coleoptera we have records of local control or suppression by birds, of beetles of nine families comprising nearly all of those including seriously destructive species. These will be taken up in order. The Biological Survey has found wireworms or adults of the family Elateridae in the stomachs of about 170 species of birds, and the value of birds as enemies of these pests has been freely acknowledged by Mr. J. A. Hyslop, of the Bureau of Entomology, specialist on the family, who says in his bulletin¹² on "Wireworms attacking cereal and forage crops," "Probably the most important factor in keeping wireworms in check are the birds."

Passing to the family Buprestidae, we have an instance by Prof. R. A. Cooley, of Montana, of effective depredations by woodpeckers upon larvæ of the flat-headed apple-tree borer (*Chrysobothris femorata*), and the statement by Dr. T. E. Snyder, of the United States Bureau of Entomology, that woodpecker enemies of the mangrove borer (*Chrysobothris tranquebarica*) often obtain a high percentage of the larvæ infesting introduced Australian pines in Florida.¹³

The long-horned wood borers also are attacked by woodpeckers, and the activities of these birds sometimes result in a considerable degree of control of the pests. Mr. Walter N. Hess says of the ribbed pine borer (*Rhagium lineatum*): "Birds, chiefly the woodpeckers, are probably the most important of the predatory enemies. It is not uncommon to find infested trees where these birds have removed from one-half to two-thirds of the larvæ and adults during a single winter."¹⁴ Mr. Fred E. Brooks has found woodpeckers to be highly effective enemies of the round-headed apple-tree borers. Of the spotted species (*Saperda cretata*) he says:

By far the most effective natural check to the increase of this borer seems to be the woodpeckers. The borers feed in positions easily accessible to these birds and empty burrows are to be found on almost every infested tree, with the marks of the birds around the wounds giving unmistakable evidence of the cause of the borer's disappearance. During the present studies every attempt to rear larvae in unprotected trees met with a loss of all the individuals as a result of woodpecker attack. * * * It seems probable that the spotted

¹⁰ Bull. N. C. Dept. Agr. 32, No. 7, July, 1911, p. 21.

¹¹ Bull. 86, U. S. Bur. Ent., 1910, p. 67.

¹² Bull. 156, U. S. Dept. Agr., 1915, p. 25.

¹³ Journ. Agr. Research 16, No. 6, Feb., 1919, p. 161.

¹⁴ Mem. 33, Cornell Agr., Exp. Sta., May, 1920, p. 379.

apple-tree borer would be a much more widely known and destructive pest were it not for the constant depletion of their numbers by woodpeckers.¹⁵

Relative to the striped species he makes still stronger statements. "While the control effect of parasites and predacious foes on this borer is negligible," he says, "woodpeckers play an important part in holding it in check. * * * In several orchards where counts were made from 50 to 75 per cent of the borers had been destroyed."¹⁶

Among the Chrysomelidæ or leaf beetles, probably the most notorious pest is the potato beetle and it is just the species for which we find recorded the most emphatic statements relating to birds as agents of control. There is on record one case of control in Wisconsin, and seven cases of local extermination occurring in Minnesota, Iowa, Illinois, Massachusetts, Pennsylvania, and South Carolina. There is one instance of local suppression of asparagus beetles by birds occurring in New York, one of control of the locust-leaf miner in Maryland, and four instances of effective depredations upon the elm-leaf beetle in Massachusetts. One writer had the temerity to venture that birds do not eat this beetle, but the cedar bird feeds freely upon it, in two recorded cases at least, exercising notable control of infestations and in two others entirely eliminating them.

Coming to the family Scarabaeidæ, we find that white grubs are the most frequent objects of investigation by economic entomologists and we learn also that high rank is invariably given to bird enemies of these pests. Dr. John J. Davis, a specialist on white grubs, gives birds first place among the natural enemies. Of his own observations he says:

Fields of timothy sod have been literally overturned by crows in their search for grubs, and in some fields the grubs were almost exterminated by them. Crows have often been observed following the plow in infested fields, eagerly picking up every grub that was unearthed.¹⁷

Mr. Norman Criddle also writes in favor of the same bird and says that while plowing he has personally observed that fully 90 per cent of white grubs exposed were picked up by crows. He is so convinced of the value of birds in controlling white grubs that he recommends that farm practice in Manitoba be planned chiefly with a view of best utilizing the services of birds in destroying white grubs; a remarkable tribute to the effectiveness of practical economic ornithology. He says:

Birds are most persistent followers of the plow during their breeding season or while migrating; gulls and terns from May 16 to June 22, and

¹⁵ Bull. 886, U. S. Dept. Agr., Oct., 1920, pp. 8-9.

¹⁶ Bull. 847, U. S. Dept. Agr., August, 1920, p. 29.

¹⁷ Farmers' Bull. No. 543, U. S. Department of Agriculture, July, 1913, p. 13.

for a short time late in July; crows and blackbirds, including grackles, from the time grubs appear in May until July 1.

From the foregoing we reach the conclusion that to attain the best possible results under conditions existing in Manitoba, plowing should be done between May 14 and July 1, and at an average depth of 5 inches. The idea is, of course, to turn up as many grubs, eggs, or pupæ as possible, a majority of which will, in all probability, be picked up by birds.¹⁸

The wireworms of the Far West usually are Tenebrionid larvæ, and it is presumed these are meant in a report by Mr. A. L. Rutherford, horticultural commissioner of Stanislaus County, Calif., in which he credits blackbirds with having eradicated the wireworms in the Turlock and Modesto irrigation districts.¹⁹

All families of weevils contain injurious species and we have records of effective destruction by birds of members of three of the families. Of one of the Otiorhynchids, the rose beetle (*Aramigus fulleri*), Mr. John G. Tyler, of Fresno, Calif., says:

One spring vast numbers of rose beetles (*Aramigus fulleri*) invaded the country about Clovis [California], and after destroying the rose flowers they took to the vineyards, doing considerable damage to the foliage by boring numerous holes through the leaves, causing them eventually to wither up and drop off. Every day for nearly a week a great flock of Brewer blackbirds hovered over a certain vineyard that I had an excellent opportunity to observe. Crawling over the branches or alighting on the topmost shoot, these black-plumaged birds were conspicuous objects against the green of the tender new foliage. As a result of the efforts of these birds, in a short time the vineyard was almost entirely free from the beetles.

Of the Curculionids, two closely related pests are known to be eaten very freely by birds. The Biological Survey has found the clover-leaf weevil (*Hypera punctata*) in the stomachs of nearly 50 species of birds, and Messrs. D. G. Tower and F. A. Fenton, authors of a Farmers' Bulletin²⁰ on this weevil, consider that "Birds are valuable and important checks on this insect." In two summers' investigation in Utah of bird enemies of the alfalfa weevil by the Biological Survey, 45 species of birds were found to attack the weevil. The killdeer was one of the most active of these, making alfalfa weevils a third of its food during part of the summer; one stomach contained no fewer than 383 individuals, 376 of them in the larval stage. The record for numbers—442 in one stomach—was held by the Brewer blackbird, an abundant species in Utah. A surprising discovery was that as a species the English sparrow was the most effective enemy of this insect; alfalfa weevils formed about a third of the food upon which its young were reared, and it was estimated that the number fed to growing English sparrows on a

¹⁸ Agr. Gaz. Can., Vol. 5, No. 5, May, 1918, pp. 449–454.

¹⁹ Weekly News Letter, Comm. Hort. Calif., Vol. 3, No. 13, April 5, 1919.

²⁰ No. 922, Dec., 1920, p. 17.

typical Utah farm was about 500,000. To this must be added the number eaten by the adult sparrows, which made of them about a fifth of their food. Most of the common birds of northeastern Utah were depending upon alfalfa weevils for almost a sixth of their entire food, and the destruction of these pests by this warfare is almost beyond conception.

The good work of birds in preying upon another weevil pest, the cotton boll weevil, must not be overlooked. Sixty-six kinds of birds are known to feed upon this formidable cotton destroyer, probably the most effective being the orioles, which actually remove the boll weevils from the place where damage begins—that is, the squares, or flower buds, of the cotton plants—and the swallows, which feed upon the weevils when in flight and extending their range. No fewer than 41 boll weevils were found in a single stomach of the Bullock oriole, and large numbers are habitually taken by all species of swallows; every one of a series of 35 eaves swallows had eaten them, the largest number in any stomach being 48, and the average 19.

All the students of bark beetles (*Scolytidae*) have been impressed with the usefulness of woodpeckers as enemies of these pests, and there are at hand six different statements indicating their control value from the pens of Dr. A. D. Hopkins, Mr. J. L. Webb, Dr. M. W. Blackman, and Dr. J. M. Swaine. We will quote only one of these, and that from Dr. Hopkins. He says with regard to the spruce-destroying bark beetle which has been responsible for the loss of many billions of feet of timber in the Northeastern States:

The principal enemy of the spruce-destroying beetle, and other bark-infesting enemies of the spruce, consists of the woodpeckers, which destroy, it is believed, from 50 to 75 per cent of the broods of the spruce beetle in many hundreds of trees each year.²¹

FLIES (DIPTERA)

Only a single instance of control by birds of a dipterous pest has come to notice, and that is one in which artificial use was made of the birds. Dr. Samuel G. Dixon, late health commissioner of Pennsylvania, writes:

After trying the ability of fish to devour larvæ and pupæ of mosquitoes with varied success, I built two dams near together on the same stream, so that each would have the same environment for the breeding of mosquitoes. Each covered nearly 1,400 square feet. In one 20 mallard ducks, *Anas platyrhyncha*, were permitted to feed, while the other was entirely protected from waterfowl, but well stocked with goldfish, *Carassius auratus* variety *americanus*.

The one in which the ducks fed was for several months entirely free from mosquitoes, while the pond protected from ducks and stocked with fish was swarming with young insects in different cycles of life.

²¹ Bull. 28, U. S. Bur. Ent., 1901, p. 48.

To the infested pond 10 well-fed mallard ducks, *Anas platyrhyncha*, were then admitted, and as they entered the pond they were first attracted by the larval batrachians, tadpoles. They, however, soon recognized the presence of larvæ and pupæ of the mosquito and immediately turned their attention to these, ravenously devouring them in preference to any other food stuffs present. At the end of 24 hours no pupæ were to be found and in 48 hours only a few small larvæ survived. The motion of the water made by the ducks, of course, drowned some of the insects—what proportion can not be estimated.

For some years I have been using ducks to keep down mosquitoes in swamps that would have been very expensive to drain, but I never fully appreciated the high degree of efficiency of the duck as a destroyer of mosquito life until the foregoing test was made.²²

LEPIDOPTERA (BUTTERFLIES AND MOTHS)

When we use the vernacular terms butterflies and moths as equivalents of the order name Lepidoptera we obscure the fact that it is the immature stages, almost exclusively, that are of economic interest. Not only are the caterpillars most important from this point of view, but they are also most important in the food of avian predators upon this order. They are devoured by nearly all kinds of insectivorous birds and are used in quantity especially for feeding the young. They are favored for this latter purpose even by numerous birds that are not highly insectivorous when adult.

The avian attack upon the immature stages of Lepidoptera is a heavy one and, as we shall see, it has resulted in numerous observed cases of control or local extermination of various pests. Representatives of 15 families of Lepidoptera are involved in these statistics and they will be taken up in order.

The larvæ of a butterfly (*Agraulis vanillæ*) of the family Nymphalidae were eaten so persistently by road runners in one case in California that, according to Mr. A. W. Anthony, a fence row covered with their food plant was entirely cleared of them. In another butterfly family are those well-known pests, the cabbage worms. Mr. Otto Lugger, former State entomologist, made an interesting observation on their vertebrate enemies in Minnesota. He had the position of 500 chrysalides of cabbage butterflies marked on a board fence and observed them through the winter to note their fate; by May 1 the number had been reduced from 500 to 43, a destruction of more than 90 per cent, chiefly by birds. Dr. J. Schneck observed in Southern Illinois one instance of complete elimination of worms from a cabbage patch by chipping sparrows.

Beginning the moths with the Sphingidae we have on record one case of local extirpation of the catalpa sphinx in Alabama by cuckoos, and two of the tomato worm in Indiana by crows. One

²² Journ. Amer. Med. Assn., Vol. 63, No. 14, p. 1203, Oct. 3, 1914.

of the latter instances was observed by Mr. Frank N. Wallace, State entomologist.

In the case of another large moth—namely, *Samia cecropia* of the family Saturniidae—the late Prof. F. M. Webster recorded the destruction of all but two of the cocoons of this species in a grove in Illinois by hairy woodpeckers. Dr. John D. Tothill, who has published so much interesting information on natural enemies of insects, concludes that in his region (Nova Scotia) nearly three-fourths of the cecropia caterpillars are eaten by orioles, robins, and other birds, and about 85 per cent of the pupæ are destroyed by woodpeckers. When M. Leopold Trouvelot was experimenting with the so-called American silkworm (*Telea polyphemus*) he found birds to be the most formidable enemies of the caterpillars, and he says: "It is probable that ninety-five out of a hundred worms become the prey of these feathered insect hunters."²³ In one case, to test the birds, he placed 2,000 of the larvæ on a tree near his door, and in a few days the birds had eaten all of them.

Excessively hairy larvæ are characteristic of the family Arctiidæ, but at least one of them, the fall webworm (*Hyphantria textor*), is freely eaten by birds. Dr. C. Gordon Hewitt informs us that, "The study of the natural control of the fall webworm was extended to Nova Scotia in 1916, and it is interesting to record that of the different factors operating in the reduction of this insect the red-eyed vireo, *Vireosylva olivacea* L., appears to be the most important. It was estimated that about 40 per cent of the larvæ had been destroyed in the webs by this bird at the five observation points."²⁴

The observations referred to are those of Doctor Tothill, who credits birds with percentages of destruction of the broods, varying in different years, from 11.4 per cent to 89.5 per cent. In 1912, when the insect was fairly plentiful, a reduction in numbers was brought about chiefly by parasites. In succeeding years the parasites gradually died out as the insect became rare, and control was maintained almost exclusively by birds.²⁵

While it may not be well known that hairy caterpillars are eaten so freely by birds, it is common knowledge that cutworms are favorite meat. Cases of local control of cutworms by birds must be of frequent occurrence. However, only the following cases seem to be on record: Three instances relating to unidentified cutworms—namely, control of ground cutworms in Massachusetts by starlings, and in Utah by meadowlarks, and of climbing cutworms in California by crows—and the following relating to identified forms. Prof. J. R.

²³ Am. Nat. I, No. 2, April, 1867, p. 89.

²⁴ Rep. Dominion Ent., 1917, p. 8.

²⁵ Proc. Ent. Soc. Nova Scotia, 1918, pp. 10-14.

Parker and associates found wild birds to be the most beneficial check upon the pale western cutworm (*Porosagrotis orthogonia*) in Montana. In Texas the boat-tailed grackle, locally called jackdaw, has several times been observed to clean up infestations of the cabbage looper (*Autographa brassicae*). The fall army worm has been extirpated from a peanut field in Florida by blackbirds, and from a millet field in Georgia by English sparrows. There are recorded instances of control of the common army worm in Canada and New York, and of local extirpation in Pennsylvania and Minnesota. Dr. Townend Glover reports that "a southern planter once stated to me that the cotton boll worm, which was destroying his cotton crop, had entirely disappeared after the visit of an immense flock of blackbirds, which, after devouring the worms, immediately left the neighborhood."²⁶

The oak caterpillars (*Datana*) are large and conspicuously colored and have threatening actions, but all these characteristics combined do not prevent attacks by birds. In the District of Columbia, Mr. Robert Ridgway observed cuckoos feeding so persistently on a colony of *Datana integerrima* on black walnut that within a week it was absolutely exterminated. The destructive Zimmerman pine moth (*Pinipestis*) of the same family has serious bird enemies, and Mr. Josef Brunner reports that in the Rocky Mountain region the hairy woodpecker is unquestionably the most efficient natural force restraining the species.

Only a few species of birds have been observed feeding on the European corn borer, but among them the woodpeckers seem to do considerable good in some cases. Messrs. G. J. Spencer and H. G. Crawford, reporting on their studies in Ontario, state that "the downy and hairy woodpeckers have frequently been seen digging the borers out of the stalks and stubbles in the field. In one field these birds were computed to have taken 60 per cent of the borers."²⁷

The tussock moth caterpillar is generally supposed to be too hairy for birds, but this is another strained assumption. When they are common in Washington, nearly every robin seen carrying food to its young shows a telltale white fluff at the end of its bill. Dr. J. M. Swaine and Mr. Alan G. Dustan report birds to be important enemies of the tussock moth in Canada, Mr. Dustan especially having made some interesting observations along this line. He found that birds and ants are responsible for holding the insect at par in forests. When he exposed larvæ to birds, the supply disappeared regularly and he credits birds with destroying half of the

²⁶ Rep. U. S. Commr. Agr. (1865) 1866, p. 42.

²⁷ Bull. 295, Ont. Dept. Agr., March, 1923, p. 7.

larvæ hatching in forests. He further says that "practically every egg mass laid above the snow line (and over 90 per cent of them are) had been either partially or wholly destroyed by birds."²⁸ Cases of local extermination of tussock moths are recorded for the English sparrows in Massachusetts and the hairy woodpecker in Ohio.

Even such obnoxiously hairy caterpillars as those of the brown-tail and gypsy moths are eaten by many birds and sometimes to an extent effective in control. Dr. L. O. Howard, chief, United States Bureau of Entomology, states that "Observations extending over a number of years show that birds are important in checking the spread of the brown-tail moth."²⁹ There has been reported to Mr. E. H. Forbush a case in which starlings had locally extirpated a mixed infestation of brown-tail and gypsy larvæ, and when Mr. Forbush was in charge of the gypsy-moth campaign for the State of Massachusetts birds were observed to so hold the gypsy moth in check at one locality for several years that work by the State force was suspended. In connection with this early work Dr. E. P. Felt was employed as entomologist, and he found it almost impossible to complete certain experiments with larvæ protected by netting bags because so many caterpillars were taken from the nets by birds. Sixty per cent of the gypsy-moth larvæ used in these experiments were destroyed by birds.

The insects of most economic importance in the next family to be taken up—namely, the Lasiocampidæ—are the tent caterpillars. These are conspicuous species and many observations have been made of their bird enemies. For the less common species known as the forest tent caterpillar (*Malacosoma disstria*) there are at hand 3 records of control and 1 of local extermination, and for the common tent caterpillar (*M. americana*), 6 of control and 9 of suppression. Entomologists contributing to these records include Misses Mary Treat and Caroline Soule, Prof. Clarence M. Weed, and Dr. John D. Tothill.

Among the Geometridæ or loopers, all smooth caterpillars, readily eaten by most birds, the larvæ of the linden-moth (*Ennomos subsignarius*) once a pest to shade trees, were so no longer after English sparrows had been introduced and became common. Dr. A. R. Grote and Dr. J. B. Smith cite cases of local extermination in New York and New Jersey, and Prof. Glenn W. Herrick says:

The testimony regarding the activity of the English sparrow in exterminating this pest in cities seems to show rather conclusively that this much-disliked bird did actually bring about the destruction of this insect. Nearly every writer on the snow-white linden-moth makes acknowledgment to the

²⁸ Proc. Acadian Ent. Soc. 1922, p. 109.

²⁹ Farmers' Bull. 264, 1906, p. 18.

sparrow and declares that the cities owe their freedom from this insect to that bird.³⁰

Cankerworms, also of the family Geometridæ, are a treat for most birds, and in special investigations of outbreaks it has been found that practically all birds of the infested region were feeding freely upon them. This has resulted in noticeable control, recorded in two cases, and in local suppression in five.

Cankerworms, as well as many of the other larvæ heretofore considered, are well exposed to birds and other enemies, but caterpillars that are concealed by no means escape, for example, larvæ of the leopard moth, which are very destructive to shade trees, but which in various localities have been noted to be held in check by native birds. "No other explanation," says Dr. W. E. Britton, "can be given of the scarcity of the leopard moth in the country, adjacent to infested towns, except the presence of insectivorous birds." * * *. Mr. James Walker, of Newark, N. J., states 'that infested elms placed in a nursery outside of the city limits of Newark were rid of the larvæ by woodpeckers.'"³¹

Among the Tortricidæ the codling moth is the greatest pest, and almost every entomologist who has written on the subject substantially agrees with Prof. M. V. Slingerland that "by far the most effective aids to man in controlling the codling moth are the birds."³² The two facts that have chiefly led to this conclusion are the great scarcity of intact hibernating cocoons and the abundance of empty ones which have evidently been rifled by birds. Long ago Messrs. Benjamin D. Walsh and C. V. Riley, noted entomological collaborators, said:³³

From the careful inspection of several large orchards in the early spring months, we are convinced that almost all of the cocoons of the apple-worm moth that have been constructed in the autumn on the trunks and limbs of apple trees are gutted of their living tenants by hungry birds long before the spring opens.

In Virginia, according to Mr. J. E. Buck, "counts of over 400 cocoons observed on apple trees revealed the fact that * * * birds had destroyed fully 85 per cent of the worms."³⁴

From New Hampshire comes this report by Dr. E. D. Sanderson:³⁵

Only 5 to 20 per cent of the larvæ survived the winter. An examination of seven trees, which averaged over 38 cocoons per tree in the fall, showed but 5 per cent alive in the spring, 87 per cent having been killed by birds, 4 per cent by disease, and 3 per cent by cold. In another orchard 1,096 cocoons

³⁰ Cornell Univ. Exp. Sta. Bull. 286, p. 62, 1910.

³¹ Ann. Rep. Conn. Agr. Exp. Sta. 1911, p. 329.

³² Bull. 142, Cornell Agr. Exp. Sta., p. 41, 1898.

³³ American Entomology, I, p. 113, 1869.

³⁴ Ann. Rep. Va. Exp. Sta., p. 55, 1908.

³⁵ Agr. Exp. Sta. Bull. 143, pp. 64 and 82, 1909.

were examined in May, 1907, with 19 per cent alive, 66 per cent having been killed by birds, 6 per cent by disease, and 9 per cent by cold. It is quite evident that the birds, particularly the downy woodpeckers and the nuthatches, are the most important enemies of the codling moth in New England, and that they should be given every protection and attracted to the orchard in every way possible.

One instance is at hand also in which a California orchard apparently was freed of codling moths by red-shafted flickers.

In relation to other Tortricidæ, Prof. W. S. Regan has stated that blackbirds do much good by feeding on the fruit-tree leaf-roller in Montana,³⁶ and Mr. E. H. Forbush records the local suppression of a spruce moth in Maine by warblers.³⁷ The spruce budworm (*Tortrix fumiferana*), a prime pest of firs and spruce, also has very effective bird enemies. In times of great abundance of the insect in New Brunswick birds were observed to take over 13 per cent of the broods, and under more normal conditions in British Columbia more than 38 per cent.³⁸ "In this case," says Doctor Tothill, "the natural checks brought about a reduction of the insect before any trees were killed, and in the following year the outbreak subsided entirely, due to continued activity of the birds against the smaller number of larvæ."

The remaining families of Lepidoptera for which we have records of effective control by birds are the Yponomeutidæ and the Elachistidæ. One of the former group, the diamond-back moth (*Plutella maculipennis*) is a cabbage pest, and Mr. J. L. Harris, of Minnesota, testifies that this insect was entirely extirpated from his patch by blackbirds. In the Elachistidæ, a forest pest again, the larch case-bearer (*Coleophora laricella*) has effective enemies among the birds. In fact, Mr. A. B. Baird says, of his New Brunswick observations, "Birds were among the chief factors in controlling this insect." The percentage of larvæ about clearings taken by birds was estimated at 75 per cent and for the area in general 25 per cent.³⁹

HYMENOPTERA (ANTS, BEES, AND WASPS)

In this order ants attract attention by their combined destructiveness and abundance and thus afford opportunity for observations on control by birds similar to those here recorded for the other orders. Flickers often are observed to suppress small colonies of ants, and Mr. J. D. Mitchell and Dr. W. Dwight Pierce have recorded the destruction of an entire swarm of agricultural ants in Texas by jackdaws.⁴⁰ Another instance of bird control of Hymenoptera is

³⁶ Circ. 109, Mont. Agr. Exp. Sta., 1922, p. 12.

³⁷ Bull. 9, Mass. Dept. Agr., 1921, p. 44.

³⁸ Tothill, John D., Proc. Acadian Ent. Soc. 8 (1922) 1923, pp. 174-176.

³⁹ Proc. Acadian Ent. Soc. 8 (1922) 1923, pp. 169-170.

⁴⁰ Proc. Ent. Soc. Wash. 14, No. 2, June 1912, p. 72.

given by Mr. S. T. Kimball, of Ellington, Conn., who states that "The oriole has cleaned my currant bushes of the currant worm⁴¹ for the past few years."

DISCUSSION

In the foregoing remarks are summarized 109 cases of control and 88 of local suppression of insects by birds. Neither of these figures is exact on account of the impossibility of reducing to numbers such expressions as: "Several times the birds were observed to clear up" certain infestations, or "many fields were kept clean," and the like. However, the exact number of recorded cases is a matter of little concern, as it can have no sort of close approach to the number that really occur. Consider, for instance, the cases of almost complete destruction of termite swarms by English sparrows that the writer has personally observed. These were three in number, and the locality of one was a telephone pole in an alley near the Bureau of Chemistry, of another a court of an apartment house on Park Road, where some porch timbers were the breeding place of termites, and of the third his own backyard in a suburb, where the lowermost riser of a flight of steps was the nursery of the white ants. Now, these are three widely separated spots in and near a city of considerable size; and the writer only by chance happened to be at each during the very brief period when it was possible to make the observation. In a city the size of Washington hundreds of such incidents must occur every season unobserved; in a thousand cities in the range of white ants, and in rural districts where the termites are subject to attack by numerous kinds of birds, there must be multiplied hundreds of cases. This, too, for only a single kind of insect; multiply again by the vast number of insects birds attack, over any one of which they may at times exercise local control, and it is evident that the number of cases occurring in the United States annually must run into the millions.

After this statement the reader may think that the author's enthusiasm as an ornithologist has overbalanced his judgment. To assure neutrality of opinion, therefore, let us leave the doings and sayings of ornithologists in abeyance and appeal to the entomologists again.

In writing about the migratory locust Dr. C. V. Riley, former Chief of the United States Bureau of Entomology, said:

While little practically can be done by man to further the multiplication of the more minute enemies of the locust, much may be done to protect and to promote the multiplication of the larger animals, especially the birds. These

⁴¹ *Pteronotus ribesii*.

should be protected by most stringent laws, firmly carried out, restraining the wanton destruction too often indulged in by sportsmen and others.⁴²

Dr. A. D. Hopkins, formerly in charge of Forest Insect Investigations, United States Bureau of Entomology, wrote in connection with his studies of insect enemies of the spruce:

I would recommend the encouragement and protection of all insectivorous birds, since they are undoubtedly of very great service in preserving a balance among the contending species of plant and animal life, and at times may render most valuable service in reducing the numbers of dangerous insect enemies.⁴³

Dr. E. P. Felt, State Entomologist of New York, also dealing with forest insects, after noting the complete destruction by English sparrows of a flight of linden-moths, states:

Insect-feeding birds appear to be the most effective checks upon such outbreaks and occurrences such as noted above are additional arguments for the better protection of birds, since under present conditions, at least, the cost of artificial control in ordinary woodland areas would be prohibitive.⁴⁴

Referring to the same insect pest Prof. Glenn W. Herrick, of Cornell University, remarks that "Undoubtedly one of the most efficient and feasible means for the control of this insect in our forests will be the better protection of our native birds."⁴⁵

Mr. Arthur Gibson, entomologist of the Dominion of Canada, after detailing the usefulness of birds as enemies of the army worm concludes:

The value of protecting our native insectivorous birds will thus readily be seen, and farmers, gardeners, etc., should do all they possibly can to protect them.⁴⁶

After calling attention to the value of birds as enemies of the tent caterpillars, Dr. J. M. Swaine, chief of the Division of Forest Insects, Canadian Department of Agriculture, puts in italics the assertion that "the protection and encouragement of our native birds would go far towards reducing the numbers of many injurious insects of orchards, shade trees, and forests."⁴⁷

Prof. V. H. Lowe, entomologist at the New York State agricultural experiment station, says:

Every thoughtful farmer knows that among the most important forces he has to contend with, in his efforts to produce abundant crops, are the hordes of insects * * *. The birds are among his most useful allies in combating these enemies.⁴⁸

⁴² U. S. Dept. Agr. Bull. 25, 1891, p. 34.

⁴³ Report on Investigations to Determine the Cause of Unhealthy Conditions of the Spruce and Pine from 1880-1893, Bull. 56, West Virginia Agr. Exp. Station, April, 1889, p. 269.

⁴⁴ 35th Rep. State Ent. N. Y. (1921), June, 1923, pp. 82 and 84.

⁴⁵ Bull. 286, Cornell Agr. Exp. Sta., Nov., 1910, p. 63.

⁴⁶ Bull. 9, Ent. Branch, Can. Dept. Agr., 1915, pp. 16-17.

⁴⁷ Ent. Circ. No. 1, Dominion Dept. Agr., 1913, p. 11.

⁴⁸ 58th Ann. Rept. N. Y. State Agr. Soc. (1898), 1899, p. 315.

Prof. C. M. Weed, formerly entomologist at both the Ohio and New Hampshire agricultural experiment stations, notes that:

After many years of study * * * of the relations of birds to agriculture, we are convinced that the birds are a most potent factor in making crop production possible, that without them we should be overrun with pests—vertebrate and invertebrate—to an extent of which we now have no conception.⁴⁹

Dr. Townend Glover, first entomologist of the United States Department of Agriculture, in one of his annual reports says:

In short, it may be plainly stated that without the cooperation of certain birds, animals, etc., this country would be overrun with insect pests.⁵⁰

And M. Leopold Trouvelot, distinguished French entomologist, whom I have quoted before in connection with bird enemies of the American silkworm, concluded from his observations that if the birds were killed off all vegetation would be destroyed by insects.

Thus it will be seen that the enthusiasm of entomologists relative to the usefulness of birds has reached the highest possible pitch, in some cases agreeing in substance with the celebrated dictum of Michelet, the French historian and essayist, that "Birds can live without man, but man can not live without the birds."

For a more reasoned statement of the utility of birds, let us quote Dr. S. A. Forbes, both an entomologist and ornithologist:

"Against the uprising of inordinate numbers of insects, commonly harmless but capable of becoming temporarily injurious," says Doctor Forbes, "The most valuable and reliable protection is undoubtedly afforded by those predacious birds and insects which eat a mixed food, so that in the absence or diminution of any one element of their food, their own numbers are not seriously affected. Resorting, then, to other food supplies, they are found ready, on occasion, for immediate and overwhelming attack against any threatening foe. Especially does the wonderful locomotive power of birds, enabling them to escape scarcity in one region which might otherwise decimate them, by simply passing to another more favorable one, without the loss of life, fit them, above all other animals and agencies, to arrest disorder at the start—to head off aspiring and destructive rebellion before it has had time fairly to make head."⁵¹

Hitherto we have considered chiefly the testimony of American observers but now let us give attention to Dr. H. Maxwell-Lefroy, the late dominion entomologist of India, since his opinion based on an extensive study of the food of birds in India, so closely parallels that of Doctor Forbes just cited.

⁴⁹ Weed, C. M., and Dearborn, N., *Birds in Their Relation to Man*, 1903, p. 4.

⁵⁰ Rep. Commr. Agr., 1870 (1871), p. 31.

⁵¹ On some Interactions of Organisms, Bull. Ill. State Laboratory of Natural History, Vol. I, No. 3, Nov., 1880, pp. 11-12.

"One has only to read the lists of the food of beneficial species of birds," says Dr. Lefroy, "to get an idea of the immense part they play in reducing insect damage. Nearly all insects have special enemies such as parasites which attack each individually, but which produce alternative abundance and scarcity of each insect; that is, with the natural action of the special checks such as parasites, you get alternative 'waves' of insect pest and parasite; this is where the birds' importance is shown; they are not restricted, they eat many kinds of insects and when a pest has for the time got ahead and is abundant, the birds are there to feed on it just because it is abundant, and because at one time, one is abundant, at another time, another is, and the birds eat them all. To put it figuratively they cut off the tops of the waves and tend to keep them all at a uniform level, none being ever destructively abundant. In my opinion from man's point of view this is the special function in nature of birds and if the bird population is small, outbreaks of insects are frequent."⁵²

In other words, entomologists, ornithologists, all of us in fact may agree, without exaggerating the services of birds in the least, that we may look upon them as an ever-present force which automatically tends to check outbreaks, large or small, among the organisms available to them as food. It is a force that should be kept at maximum efficiency by protective measures and which should be taken into consideration and used whenever possible. At the same time we must not neglect to credit with their good services, and to protect and adapt to our ends so far as practicable, other insect-destroying vertebrates. Among these certain toads, lizards, shrews, and moles, may in their more restricted spheres, at times approach birds in individual efficiency, and bats may equal them. Various other mammals, reptiles, amphibians, and fishes also have value as insect foes which should not be overlooked. Let us prize them all according to their deserts, and utilize their services as best we may.

⁵² In Mason, C. W. *The Food of Birds in India*. Mem. Dept. Agr. India Ent. Ser. Vol. III, Jan., 1912, p. 364.

